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# Association of different hemovac drainage management protocols on hemoglobin decrease, drainage volume, and blood transfusion requirements in total knee and hip arthroplasty: A retrospective cohort study

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**Abstract**

To examine whether the modified Hemovac protocol—which involves a 16-hour delay in negative-pressure activation and the application of intermittent temporary passive drainage—differs from immediate continuous negative-pressure drainage regarding early blood-loss-related outcomes and wound findings following primary total knee arthroplasty (TKA) or total hip arthroplasty (THA). Medical records of 200 patients who underwent primary TKA (n = 100) or THA (n = 100) between January 14, 2002, and December 20, 2007, were reviewed retrospectively. Within each arthroplasty type, 50 patients received immediate continuous negative-pressure drainage for the first 24 postoperative hours and 50 underwent a modified protocol in which negative-pressure activation was delayed for the first 16 hours, intermittent temporary passive drainage was applied during this period, and the drain was activated under negative pressure at the 16th hour. The analysis included preoperative and postoperative day 3 hemoglobin, hemoglobin decline, 24-hour drainage volume, allogeneic red blood cell transfusion, hospital stay, wound-site ecchymosis, and wound leakage. Baseline demographic and clinical characteristics were comparable between the drain-protocol groups within both arthroplasty types (all $p > 0.05$). The modified protocol was associated with a higher postoperative day 3 hemoglobin level and a smaller hemoglobin decline in both TKA and THA (all $p < 0.001$). Patients in the modified groups also had lower 24-hour drainage volumes, fewer transfusions, fewer transfused red blood cell units, and shorter hospital stays (all $p < 0.05$). Wound-site ecchymosis was less frequent with the modified protocol in TKA ($p = 0.003$), whereas no statistically significant difference was observed in THA ($p = 0.081$). Wound leakage did not differ significantly between protocols in either TKA ($p = 0.050$) or THA ($p = 0.715$). In this retrospective cohort, delayed Hemovac activation was associated with less postoperative drainage, a smaller decrease in hemoglobin, and lower transfusion use after both TKA and THA. The protocol was not associated with a higher frequency of wound leakage. Prospective studies conducted within contemporary blood-management pathways are needed to confirm these findings.

**Keywords:** Total knee arthroplasty, total hip arthroplasty, Hemovac drain, drainage volume, allogeneic blood transfusion, closed-suction drainage

## Introduction

Perioperative blood loss remains a clinically relevant concern in total knee arthroplasty (TKA) and total hip arthroplasty (THA). The resulting postoperative decrease in hemoglobin may necessitate allogeneic red blood cell transfusion, particularly in patients with limited hematologic reserve or substantial surgical blood loss [1–3]. Because blood transfusions carry clinical risks and increase healthcare costs, minimizing perioperative blood loss is a crucial aspect of total joint arthroplasty care.

Several strategies have been developed to minimize surgical bleeding and lower the need for transfusions [4–13]. These approaches include administering tranexamic acid, applying controlled hypotension and tourniquets, ensuring precise surgical hemostasis, maintaining strict transfusion thresholds, and utilizing

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comprehensive patient blood management programs. Drain management represents another potentially modifiable component of perioperative care. However, routine drainage after joint arthroplasty remains controversial, and there is no clear consensus regarding the timing of negative-pressure activation [14–16].

Closed-suction drains are used to remove fluid from the surgical site and reduce postoperative hematoma accumulation [17–20]. Immediate negative pressure, however, may disrupt the early tamponade effect within the operative field and prolong bleeding. Delayed activation or temporary clamping may help preserve this effect and reduce drainage volume [14,17–22]. Conversely, prolonged clamping may increase the risk of hematoma formation, wound leakage, swelling, or other local wound problems. The duration that provides an appropriate balance between these potential benefits and risks remains uncertain [14,19,21,22].

Previous studies of drain clamping and delayed suction have reported inconsistent findings [4,17–23]. The majority of previous research has evaluated TKA. In contrast, THA studies typically compare closed-suction drainage directly against no drainage. Therefore, there is limited evidence evaluating the exact same delayed-activation protocol for both TKA and THA procedures.

This study evaluated whether the modified Hemovac protocol, in which negative-pressure activation was delayed for 16 hours and intermittent temporary passive drainage was applied after primary TKA or THA, was associated with postoperative hemoglobin loss, drainage volume, and transfusion requirements compared with immediate continuous negative-pressure drainage. Length of hospital stay and early wound findings were also assessed. We hypothesized that the modified protocol would be associated with lower blood-loss-related outcomes without an adverse difference in early wound recovery.

## Material and Methods

### Study Design and Procedures

This single-center, retrospective, comparative clinical study was designed to evaluate the relationships between different Hemovac drain management protocols and postoperative hemoglobin decline, drainage volume, the requirement for allogeneic red blood cell transfusion, and early wound complications in patients undergoing primary TKA or primary THA. Approval for the study was obtained from the Samsun University Non-Interventional Clinical Research Ethics Committee (Decision No: GOKAEK 2026/13/3; Date: July 22, 2026). The requirement for informed consent was waived by the ethics committee due to the retrospective, observational nature of the study.

The study was based on the retrospective analysis of systematically maintained clinical records from surgical procedures performed between January 14, 2002, and December 20, 2007, following ethics committee approval. At the beginning of the study period, conventional Hemovac drain management was routinely used for primary TKA and THA procedures at our institution. However, beginning in 2005, the drain management protocol was modified based on the contemporary literature and clinical experience suggesting that continuous negative-pressure drainage during the early postoperative period might increase blood loss by reducing the physiological tamponade effect within the surgical field. Thereafter, a modified Hemovac drain management protocol, in which the drain was kept closed for the first 16 postoperative hours and subsequently activated under negative pressure, was routinely implemented in consecutive patients. The present study retrospectively compared the outcomes of these two drain management approaches, both of which were standard clinical practice during their respective periods.

Patients were retrospectively classified into two groups based on the Hemovac drain management protocol used during the surgical period. After predefined inclusion and exclusion criteria were applied, 50 consecutive patients meeting the eligibility criteria for each surgical procedure and drain management protocol were included in the study. Accordingly, a total of 200 patients were analyzed, comprising 50 TKA and 50 THA patients in the conventional Hemovac group, and 50 TKA and 50 THA patients in the modified Hemovac group. The sample size of 50 patients in each subgroup was not determined based on a prospective power analysis but was based on the inclusion of consecutive patients meeting the eligibility criteria during the relevant periods within the scope of the study design.

**Group 1: Conventional Hemovac Drain Management**

This group comprised 100 patients, including 50 who underwent primary TKA and 50 who underwent primary THA. Immediately after completion of the surgical procedure, the Hemovac drain was activated under negative pressure, providing continuous active drainage throughout the first 24 postoperative hours.

**Group 2: Modified Hemovac Drain Management**

This group comprised 100 patients, including 50 who underwent primary TKA and 50 who underwent primary THA. At the end of the surgical procedure, the Hemovac drain was left closed without negative pressure, and negative-pressure activation was delayed until the 16th postoperative hour. During this period, intermittent temporary passive drainage was applied as a planned component of the protocol to reduce the tension, sensation of pressure, and pain developing at the surgical site. In all patients in the modified Hemovac group (100/100, 100%), the Hemovac drain was opened without applying negative pressure for passive drainage for approximately 10 minutes at least three times during the first 16 hours, after which it was reclamped. At the end of the 16th postoperative hour, the drain was activated under

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negative pressure, and active drainage was maintained until the 24th postoperative hour. The purpose of this protocol was to reduce the pressure in the surgical field through intermittent passive drainage while delaying continuous negative-pressure drainage in the early postoperative period, and to preserve the early tamponade effect as much as possible.

Primary TKA was performed in all patients through a standard medial parapatellar approach. All procedures were performed under spinal anesthesia with a pneumatic tourniquet inflated to 300 mmHg, and a cemented posterior-stabilized knee prosthesis was implanted. The operative duration was approximately 75 minutes, and tourniquet time ranged from 45 to 60 minutes. At the end of the surgical procedure, the tourniquet was released, and meticulous hemostasis was achieved. Primary THA was performed in all patients through a standard posterolateral approach. All procedures were performed under spinal anesthesia, and an uncemented total hip prosthesis was implanted according to the clinical indication. The mean operative duration was approximately 105 minutes, with individual operative times ranging from 90 to 120 minutes.

Standardized perioperative antibiotic prophylaxis, venous thromboembolism prophylaxis, and postoperative rehabilitation protocols were applied in both surgical groups. All patients also received the same postoperative analgesia protocol. At the end of surgery, patient-controlled analgesia using a tramadol-containing pump was initiated, and supplementary intravenous paracetamol was administered when required. All surgical procedures were performed by the same experienced orthopedic surgeon (AKY). Tranexamic acid was not administered to any patient during the perioperative period.

Complete blood counts were assessed preoperatively, at the eighth postoperative hour, and on postoperative days 1, 2, 3, 4, and 5. Postoperative drainage was recorded as the total volume of fluid collected from the drain during the first 24 postoperative hours, expressed in milliliters. All Hemovac drains were removed at the 24th postoperative hour. Length of hospital stay, the requirement for allogeneic red blood cell transfusion, and early wound complications, including wound-site ecchymosis and wound leakage, were recorded and analyzed. A restrictive transfusion strategy was adopted for allogeneic red blood cell transfusion, with a hemoglobin threshold of 8 g/dL [20].

The inclusion criteria were as follows: undergoing primary TKA or THA for primary knee or hip osteoarthritis; having all surgical procedures performed by the same surgical team; use of the same implant system; application of the same postoperative thromboprophylaxis protocol; and availability of complete preoperative and postoperative laboratory data. The exclusion criteria were as follows: revision TKA or THA; simultaneous bilateral TKA; periprosthetic fracture; inflammatory arthritis; history of malignancy; active infection; preoperative hemoglobin level below 10 g/dL; coagulation disorders; and incomplete clinical records.

### Statistical Analyses

The distribution of the data was assessed for normality, and parametric or nonparametric statistical methods were selected accordingly. The independent-samples Student's t-test was used to compare normally distributed continuous variables between two groups, whereas the Mann–Whitney U test was used for variables that did not follow a normal distribution. Categorical variables were analyzed using the chi-square test. Fisher's exact test was used when the assumptions of the chi-square test were not met, particularly when more than 20% of the expected cell frequencies were below 5. Descriptive statistics were presented as the mean ± standard deviation for parametric data, median (minimum–maximum) for nonparametric data, and number (n) and percentage (%) for categorical variables. Effect sizes were calculated according to variable type and distribution. Cohen's d was used for normally distributed continuous variables, Cliff's delta for non-normally distributed continuous variables, and Cramer's V for categorical variables. All statistical analyses were performed using IBM SPSS Statistics (IBM Corp., Armonk, NY, USA), and a two-sided p value of $< 0.05$ was considered statistically significant.

## Results

Demographic and clinical characteristics of the four study groups are presented in Table 1. When comparing the conventional and modified Hemovac subgroups in the primary TKA and primary THA groups, no statistically significant differences were found between the groups according to the independent samples t-test for age and body mass index (BMI), and the Chi-square or Fisher's exact test results for gender distribution, American Society of Anesthesiology (ASA) physical status score, and presence of concomitant comorbidities (all $p > 0.05$). The low levels of calculated Cohen's d and Cramer's V effect sizes also support the idea that the differences between the groups are clinically insignificant.

Table 2 presents the comparison of perioperative hemoglobin levels in the primary TKA and primary THA groups. In both surgical groups, no statistically significant difference was found between conventional and modified Hemovac groups in terms of preoperative hemoglobin levels (TKA: $p = 0.681$, Cohen's d = -0.083; THA: $p = 0.742$, Cohen's d = 0.066) and the calculated effect sizes were found to be negligible. In contrast, hemoglobin levels on postoperative day 3 were significantly higher in the modified Hemovac group than in the conventional Hemovac group among both TKA and THA patients ($p < 0.001$ for both comparisons). The effect sizes accompanying this difference were found to be large (Cohen's d = -1.421) and moderate-to-large (Cohen's d = -0.863), respectively. Furthermore, the reduction in hemoglobin levels was significantly smaller in patients managed with the modified Hemovac protocol than in those managed with the conventional protocol in both the TKA and THA groups ($p < 0.001$ for both comparisons). The effect sizes corresponding to this finding were also found to be large (Cohen's d = 0.951 and 1.079, respectively).

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**Table 1.** Demographic and clinical characteristics of study groups

| Variables | Hemovac type | | p | ES |
|---|---|---|---|---|
| **TKA** | **Conventional (n = 50)** | **Modified (n = 50)** | | |
| **Age (years)** | 64.44 ± 7.61 | 65.30 ± 6.79 | 0.552 | -0.119 |
| **Gender (Female/Male), n (%)** | 45 (90.0)<br>5 (10.0) | 46 (92.0)<br>4 (8.0) | 1.000† | 0.035 |
| **Body mass index (kg/m²)** | 29.51 ± 2.52 | 29.91 ± 2.72 | 0.451 | -0.151 |
| **ASA score (I/II), n (%)** | 16 (32.0)<br>34 (68.0) | 15 (30.0)<br>35 (70.0) | 0.829 | 0.022 |
| **Presence of additional diseases, n (%)** | 32 (64.0) | 31 (62.0) | 0.836 | 0.021 |
| **THA** | **Conventional (n = 50)** | **Modified (n = 50)** | **p** | **ES** |
| **Age (years)** | 63.74 ± 7.41 | 64.04 ± 10.22 | 0.867 | -0.034 |
| **Gender (Female/Male), n (%)** | 36 (72.0)<br>14 (28.0) | 35 (70.0)<br>15 (30.0) | 0.826 | 0.022 |
| **Body mass index (kg/m²)** | 29.11 ± 3.20 | 29.75 ± 3.91 | 0.373 | -0.179 |
| **ASA score (I/II), n (%)** | 30 (60.0)<br>20 (40.0) | 28 (56.0)<br>22 (44.0) | 0.685 | 0.041 |
| **Presence of additional diseases, n (%)** | 27 (54.0) | 32 (64.0) | 0.309 | 0.102 |

†Fisher's exact test; Continuous variables were compared using the independent-samples Student's t-test, and categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate; Effect sizes were expressed as Cohen's d for continuous variables and Cramer's V for categorical variables; TKA: total knee arthroplasty, THA: total hip arthroplasty, ES: effect size

**Table 2.** Comparison of perioperative hemoglobin levels and hemoglobin changes in TKA and THA groups

| Variables | Hemovac type | | p | ES |
|---|---|---|---|---|
| **TKA** | **Conventional (n = 50)** | **Modified (n = 50)** | | |
| **Preoperative hemoglobin (g/dL)** | 12.62 ± 0.93 | 12.70 ± 0.96 | 0.681 | -0.083 |
| **Postoperative day 3 hemoglobin (g/dL)** | 8.27 ± 0.55 | 9.15 ± 0.68 | **< 0.001*** | -1.421 |
| **Hemoglobin decrease (g/dL)** | 4.36 ± 0.82 | 3.55 ± 0.87 | **< 0.001*** | 0.951 |
| **THA** | **Conventional (n = 50)** | **Modified (n = 50)** | **p** | **ES** |
| **Preoperative hemoglobin (g/dL)** | 13.10 ± 0.87 | 13.03 ± 1.27 | 0.742 | 0.066 |
| **Postoperative day 3 hemoglobin (g/dL)** | 8.74 ± 0.81 | 9.56 ± 1.08 | **< 0.001*** | -0.863 |
| **Hemoglobin decrease (g/dL)** | 4.36 ± 0.81 | 3.46 ± 0.85 | **< 0.001*** | 1.079 |

*p < 0.05; Continuous variables were compared using the independent-samples Student's t-test; Effect sizes were expressed as Cohen's d; TKA: total knee arthroplasty, THA: total hip arthroplasty, ES: effect size

Table 3 presents the early postoperative outcomes associated with the conventional and modified Hemovac drain management protocols in the primary TKA and primary THA groups. The drainage volume during the first 24 postoperative hours was significantly lower in patients managed with the modified Hemovac protocol than in those managed with the conventional protocol in both the TKA and THA groups ($p < 0.001$ for both comparisons). The Cohen's d values accompanying this difference (TKA: 10.669; THA: 3.540) were found to be very large.

Similarly, the requirement for allogeneic red blood cell transfusion and the number of red blood cell units transfused were significantly lower in the modified Hemovac group than in the conventional Hemovac group for both surgical procedures (all $p < 0.05$). In addition, the length of hospital stay was significantly shorter in patients managed with the modified Hemovac protocol in both the TKA and THA groups ($p < 0.001$ for both comparisons). Similarly, the need for allogeneic erythrocyte suspension transfusion (TKA: $p < 0.001$, Cramer's V = 0.524; THA: $p = 0.006$, Cramer's V = 0.274) and the proportion of patients receiving 2 units of transfusion (TKA: $p < 0.001$, Cramer's V = 0.639; THA: $p < 0.001$, Cramer's V = 0.333) were significantly lower in the modified Hemovac group compared to the conventional Hemovac group in both surgical groups, with effect sizes ranging from moderate to strong. In contrast, no significant difference was found between the groups in terms of the proportion of patients receiving 1 unit of transfusion (TKA: $p = 0.401$, Cramer's V = 0.084; THA: $p = 0.585$, Cramer's V = 0.055). Furthermore, hospital stay was found to be significantly shorter in both TKA and THA patients in the modified Hemovac group ($p < 0.001$ for both groups), and Cliff's d values (TKA: 0.840; THA: 1.000) indicated a very strong effect.

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Regarding early wound complications, the incidence of wound-site ecchymosis was significantly lower in patients receiving the modified Hemovac protocol than in those receiving the conventional protocol in the TKA group (p = 0.003, Cramer's V = 0.300), whereas no statistically significant difference was observed in the THA group (p = 0.081, Cramer's V = 0.175). Furthermore, no statistically significant difference was found between conventional and modified Hemovac applications in terms of wound leakage in either the TKA or THA groups (TKA: p = 0.050, Cramer's V = 0.196; THA: p = 0.715, Cramer's V = 0.074), and the effect sizes remained weak in both comparisons.

Table 4 presents a comparison of perioperative hemoglobin levels and early postoperative clinical outcomes between patients undergoing primary TKA and those undergoing primary THA within the conventional and modified Hemovac drain management protocols. In the conventional Hemovac group, preoperative hemoglobin levels and hemoglobin levels on postoperative day 3 were significantly higher in THA patients than in TKA patients (p = 0.009 and p < 0.001, respectively). The effect sizes corresponding to these differences (Cohen's d = -0.530 and -0.683) were found to be moderate. However, no statistically significant difference was observed between the two surgical groups in the magnitude of postoperative hemoglobin reduction (p = 0.980, Cohen's d = -0.005). In the modified Hemovac group, postoperative day 3 hemoglobin level was significantly higher in the THA group than in the TKA group (p = 0.025, Cohen's d = -0.458), indicating a moderate effect size. No statistically significant differences were observed between the TKA and THA groups in preoperative hemoglobin level or hemoglobin decrease (p > 0.05 for both).

The drainage volume during the first 24 postoperative hours was significantly lower in THA patients than in TKA patients in both the conventional and modified Hemovac groups (p < 0.01 for both comparisons). A very large effect size (Cohen's d = 2.972) was calculated in the conventional group, while a moderate-to-large effect size (Cohen's d = 0.589) was found in the modified group. In the conventional Hemovac group, the requirement for allogeneic red blood cell transfusion, the number of red blood cell units transfused, length of hospital stay, and incidence of wound-site ecchymosis were also significantly lower in THA patients than in TKA patients (p = 0.001, p < 0.001, p = 0.003, and p = 0.005, respectively). The effect sizes accompanying these differences (Cramer's V = 0.321; Cramer's V = 0.390; Cliff's d = 0.160; Cramer's V = 0.280) were found to range from weak to moderate. In contrast, within the modified Hemovac group, no statistically significant differences were observed between the TKA and THA groups in these outcomes or in the incidence of wound leakage (all p > 0.05).

**Table 3.** Comparison of drainage, blood transfusion, and early postoperative outcomes in the first 24 hours in TKA and THA groups

| Variables | Hemovac type | | p | ES |
|---|---|---|---|---|
| **TKA** | **Conventional (n = 50)** | **Modified (n = 50)** | | |
| **Total drainage amount from the Hemovac in the first 24 hours (mL)** | 765.0 ± 44.3 | 324.0 ± 38.1 | **< 0.001*** | 10.669 |
| **Patient who received blood transfusion, n (%)** | 35 (70.0) | 9 (18.0) | **< 0.001*** | 0.524 |
| **Patients who received 1 unit of transfusion, n (%)** | 6 (12.0) | 9 (18.0) | 0.401 | 0.084 |
| **Patients who received 2 units of transfusion, n (%)** | 29 (58.0) | 0 (0.0) | **< 0.001*** | 0.639 |
| **Hospital stay (days) median (min-max)** | 7 (5-7) | 5 (5-5) | **< 0.001*** | 0.840 |
| **Wound site ecchymosis, n (%)** | 33 (66.0) | 18 (36.0) | **0.003*** | 0.300 |
| **Wound site leakage, n (%)** | 11 (22.0) | 4 (8.0) | 0.050 | 0.196 |
| **THA** | **Conventional (n = 50)** | **Modified (n = 50)** | **p** | **ES** |
| **Total drainage amount from the Hemovac in the first 24 hours (mL)** | 560.0 ± 86.9 | 294.0 ± 61.1 | **< 0.001*** | 3.540 |
| **Patient who received blood transfusion, n (%)** | 19 (38.0) | 7 (14.0) | **0.006*** | 0.274 |
| **Patients who received 1 unit of transfusion, n (%)** | 9 (18.0) | 7 (14.0) | 0.585 | 0.055 |
| **Patients who received 2 units of transfusion, n (%)** | 10 (20.0) | 0 (0.0) | **< 0.001*** | 0.333 |
| **Hospital stay (days) median (min-max)** | 7 (7-7) | 5 (5-5) | **< 0.001*** | 1.000 |
| **Wound site ecchymosis, n (%)** | 19 (38.0) | 11 (22.0) | 0.081 | 0.175 |
| **Wound site leakage, n (%)** | 5 (10.0) | 3 (6.0) | 0.715† | 0.074 |

*p < 0.05; †Fisher's exact test; Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate; Normally distributed continuous variables were compared using the independent-samples Student's t-test, and non-normally distributed continuous variables were compared using the Mann–Whitney U test; Effect sizes were expressed as Cramer's V for categorical variables, Cohen's d for normally distributed continuous variables, and Cliff's delta for non-normally distributed continuous variables; TKA: total knee arthroplasty, THA: total hip arthroplasty, ES: effect size

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**Table 4.** Comparison of perioperative hemoglobin levels and early clinical outcomes in study groups

| Variables | Type of surgery | | p | ES |
|---|---|---|---|---|
| **Conventional** | **TKA (n = 50)** | **THA (n = 50)** | | |
| **Preoperative hemoglobin (g/dL)** | 12.62 ± 0.93 | 13.10 ± 0.87 | **0.009*** | -0.530 |
| **Postoperative day 3 hemoglobin (g/dL)** | 8.27 ± 0.55 | 8.74 ± 0.81 | **< 0.001*** | -0.683 |
| **Hemoglobin decrease (g/dL)** | 4.36 ± 0.82 | 4.36 ± 0.81 | 0.980 | -0.005 |
| **Total drainage amount in the first 24 hours (mL)** | 765.0 ± 44.3 | 560.0 ± 86.9 | **< 0.001*** | 2.972 |
| **Patient who received blood transfusion, n (%)** | 35 (70.0) | 19 (38.0) | **0.001*** | 0.321 |
| **Patients who received 1 unit of transfusion, n (%)** | 6 (12.0) | 9 (18.0) | 0.401 | 0.084 |
| **Patients who received 2 units of transfusion, n (%)** | 29 (58.0) | 10 (20.0) | **< 0.001*** | 0.390 |
| **Hospital stay (days) median (min-max)** | 7 (5-7) | 7 (7-7) | **0.003*** | 0.160 |
| **Wound site ecchymosis, n (%)** | 33 (66.0) | 19 (38.0) | **0.005*** | 0.280 |
| **Wound site leakage, n (%)** | 11 (22.0) | 5 (10.0) | 0.102 | 0.164 |
| **Variables** | **Type of surgery** | | **p** | **ES** |
| **Modified** | **TKA (n = 50)** | **THA (n = 50)** | | |
| **Preoperative hemoglobin (g/dL)** | 12.70 ± 0.96 | 13.03 ± 1.27 | 0.152 | -0.289 |
| **Postoperative day 3 hemoglobin (g/dL)** | 9.15 ± 0.68 | 9.56 ± 1.08 | **0.025*** | -0.458 |
| **Hemoglobin decrease (g/dL)** | 3.55 ± 0.87 | 3.46 ± 0.85 | 0.610 | 0.102 |
| **Total drainage amount in the first 24 hours (mL)** | 324.0 ± 38.1 | 294.0 ± 61.1 | **0.004*** | 0.589 |
| **Patient who received blood transfusion, n (%)** | 9 (18.0) | 7 (14.0) | 0.585 | 0.055 |
| **Patients who received 1 unit of transfusion, n (%)** | 9 (18.0) | 7 (14.0) | 0.585 | 0.055 |
| **Patients who received 2 units of transfusion, n (%)** | 0 (0.0) | 0 (0.0) | - | - |
| **Hospital stay (days) median (min-max)** | 5 (5-5) | 5 (5-5) | 1.000 | 0.000 |
| **Wound site ecchymosis, n (%)** | 18 (36.0) | 11 (22.0) | 0.123 | 0.154 |
| **Wound site leakage, n (%)** | 4 (8.0) | 3 (6.0) | 1.000 | 0.039 |

*p < 0.05; Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate; Normally distributed continuous variables were compared using the independent-samples Student's t-test, and non-normally distributed continuous variables were compared using the Mann–Whitney U test; Effect sizes were expressed as Cramer's V for categorical variables, Cohen's d for normally distributed continuous variables, and Cliff's delta for non-normally distributed continuous variables; TKA: total knee arthroplasty, THA: total hip arthroplasty, ES: effect size

## Discussion

In this retrospective study, the modified Hemovac protocol, in which negative-pressure activation was delayed for the first 16 hours and intermittent temporary passive drainage was applied during this period, was associated with lower 24-hour drainage volume and a reduced requirement for allogeneic red blood cell transfusion after primary TKA and THA compared with continuous negative-pressure drainage immediately after surgery. Patients managed with the modified protocol also had higher postoperative hemoglobin levels and a smaller decrease in hemoglobin from baseline. Partial preservation of the early tamponade effect within the operative field may have contributed to these findings; however, this mechanism was not directly evaluated in this study.

Perioperative blood loss and transfusion remain clinically relevant concerns after total joint arthroplasty because of their associations with postoperative complications, longer hospitalization, and increased healthcare use [1–3]. Current patient blood management strategies include tranexamic acid (TXA), restrictive transfusion thresholds, careful surgical hemostasis, and multimodal blood-conservation protocols [8–10,13]. Our findings suggest that a drain management approach involving the timing of negative-pressure activation and intermittent passive drainage in the early period may be associated with blood-loss-related outcomes, such as postoperative hemoglobin decline, drainage volume, and transfusion requirements. This finding is consistent with previous randomized trials and meta-analyses reporting an association between temporary clamping or delayed suction and lower drainage volume, total blood loss, and transfusion requirements [4–7,14,21,22,24]. However, other systematic reviews have found insufficient evidence to support the routine use of closed-suction drainage after joint arthroplasty [16–20]. These differing results may partly reflect variations in drain type, clamping duration, suction pressure, perioperative blood management, and surgical procedure. Güven et al. reported lower postoperative drainage volume with mobilization-based Hemovac management after knee arthroplasty [25]. Our findings extend this observation by examining the same delayed-activation approach in both TKA and THA patients.

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In comparisons within the drain protocols, no statistically significant difference was found between TKA and THA patients in terms of postoperative hemoglobin decline. However, in the conventional Hemovac group, the transfusion requirement was higher in TKA patients than in THA patients; whereas in the modified Hemovac group, no significant difference was found between TKA and THA in terms of transfusion requirements. Previous studies have attributed bleeding after TKA to factors such as synovial resection, exposed cancellous bone surfaces, and increased fibrinolytic activity after tourniquet release [1–3,10–13,26–28]. In THA, a greater proportion of bleeding may occur during surgical exposure and preparation of the femoral canal, with comparatively less continuing drainage during the postoperative period [13]. Large patient series have identified several patient- and procedure-related predictors of transfusion after TKA and THA, with the amount of perioperative blood loss being an important determinant [1–3,29,30]. The higher transfusion requirement observed in TKA patients in the conventional Hemovac group should not be explained solely by differences in blood loss, given that there was no significant difference in hemoglobin decline between TKA and THA. While delayed drain activation produced positive results for both surgeries, future studies using procedure-specific statistical analyses are necessary to determine if the protocol benefits TKA and THA differently.

Early wound-site ecchymosis was more frequent among patients with higher drainage volumes and greater transfusion requirements. Ecchymosis may reflect extravasation of blood into the subcutaneous tissues and may therefore accompany greater local postoperative bleeding. Previous studies have linked increased perioperative blood loss and transfusion with higher postoperative complication rates [1–3,26–29,31], while studies of drain use have reported local findings such as hematoma, swelling, wound leakage, and ecchymosis [7,14–25]. Nevertheless, ecchymosis is influenced by several factors and should not be regarded as a direct measure of surgical blood loss. Anticoagulant treatment, age, vascular and skin fragility, surgical technique, and the degree of soft-tissue trauma may also contribute. Because of the retrospective design, the observed relationships among drainage volume, transfusion, and ecchymosis cannot be interpreted as causal.

This study has several limitations. It was conducted retrospectively at a single center and included only early postoperative outcomes. Deep infection, revision surgery, and other long-term complications were therefore not evaluated. In addition, the conventional and modified protocols were used during different time periods. Changes in surgical experience, perioperative care, transfusion practice, or patient management over time may consequently have influenced the results. Particularly, the difference observed between the groups in the length of hospital stay may have been influenced by changes in discharge criteria, rehabilitation practices, and other perioperative care processes across different historical periods, independent of the drain management protocol itself. Therefore, the difference in hospital stay should not be interpreted directly as an effect of the modified Hemovac protocol. All procedures were performed by the same surgeon at the same institution using similar surgical techniques and perioperative protocols, which reduced some procedural variability but did not eliminate the possibility of temporal confounding. The findings should therefore be interpreted as associations between drain management and postoperative outcomes rather than evidence of a causal effect. Furthermore, the modified protocol included the application of intermittent temporary passive drainage during this period in addition to the 16-hour delay of negative-pressure activation. Therefore, the retrospective design of the study does not allow the separation of the independent contributions of delayed negative-pressure activation and intermittent passive drainage to the observed outcomes.

The 16-hour interval was based on the modified Hemovac protocol used at our institution and was not selected through a comparison of different clamping durations. Thus, the study does not determine the optimal time for negative-pressure activation. TXA was also not administered during the study period. Although this allowed the two drain protocols to be compared under similar conditions, it limits the applicability of the results to current arthroplasty practice, in which TXA is commonly included in perioperative blood management. Relevant strengths include the use of consistent surgical practice, the inclusion of both TKA and THA, and the assessment of two drain protocols used in routine clinical care. Prospective studies should compare different activation intervals and determine whether the observed effects remain present when delayed drainage is combined with contemporary TXA-based blood management protocols.

## Conclusion

The modified Hemovac protocol, in which negative-pressure activation was delayed for the first 16 hours and intermittent temporary passive drainage was applied during this period, was associated with a lower 24-hour drainage volume, a smaller postoperative decrease in hemoglobin, fewer allogeneic red blood cell transfusions, and a shorter hospital stay compared with immediate continuous negative-pressure drainage after primary TKA and THA. No meaningful increase in the evaluated early wound findings was observed. These results support further investigation of drain management strategies involving the timing of negative-pressure activation and early passive drainage application; however, causal or long-term conclusions cannot be drawn from this retrospective study.

**Ethical Approval**

*Ethical approval was obtained from the Samsun University Non-Interventional Clinical Research Ethics CommitteeDecision No: GOKAEK 2026/13/3; Date: July 22, 2026.*

**Patient Consent**

*The requirement for informed consent was waived by the ethics committee due to the retrospective, observational nature of the study.*

**Conflict of Interest**
*The authors confirm the absence of any conflicts associated with this work.*

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